

# Hydration: The New FIFA World Cup's Challenge for Referee Decision Making?

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Various continental sporting events have exposed team sports referees to different environmental conditions. Several studies have focused on strategies to prevent athlete performance impairment induced by heat or warm (or both) conditions, but few authors have investigated the effect of heat on referees' performance. In a thermoneutral environment, referees' physical activity induced mild 2.0% dehydration, which was

responsible for reductions in physical, psychomotor, and cognitive performances. Therefore, the hydration status of referees should be taken into account to reduce referees' errors and misjudgments in the heat.

**Key Words:** heat, team sports, Laws of the Game, error in judgment

## Key Points

- Mild dehydration (ie, 2% of weight loss) induced by match play could impair the physical and cognitive performance of soccer referees in temperate conditions.
- Referees' thirst sensation negatively affected the speed of responding.
- Heat exacerbated the effect of physical activity on referees' decision-making error.
- Adequate hydration for referees before the game and quick, easy access to fluid during matches could be good strategies to prevent thirst and misjudgments associated with physical exercise in the heat.

Various continental sporting events have exposed team-sport players to different environmental conditions. In the present decade, at least 5 main Federation Internationale de Football Association (FIFA) competitions have been or will be organized in a hot environment with or without a high degree of humidity<sup>1</sup>: FIFA U-17 men's (United Arab Emirates, 2013)<sup>2</sup> and women's (Costa Rica, 2014) World Cups,<sup>3</sup> Youth Olympic Football Tournament (Nanjing, China, 2014),<sup>4</sup> and FIFA World Cup in Brazil (2014)<sup>5</sup> and in Qatar (2022).<sup>6</sup> Due to its impressive geographic size and location, the FIFA World Cup host, the Federative Republic of Brazil, offered a wide range of weather conditions from moderate to tropical monsoon climates.<sup>3,7,8,9</sup> During the tournament, soccer players of the qualified teams and referees were exposed to a large range of heat and humidity conditions. During the USA versus Portugal game, the first-ever water break was allowed by the referee, given the severely hot conditions experienced. Water breaks are allowed by FIFA rules any time after 30 minutes into a game played in extreme heat, but they are not mandatory.<sup>10</sup> The referee's decision followed a Brazilian court's temporary injunction making water breaks near the 30th minute of each half mandatory when temperatures reach 32°C in the wet-bulb globe temperature index, which takes into account factors such as time of day, cloud cover, wind, humidity, and location.<sup>10</sup> Several studies (see the reviews of Maughan et al<sup>11</sup> and Shirreffs<sup>12</sup>) have focused on strategies to prevent

the physiologic and psychological impairments in athletic performance induced by team-sport games performed in warm conditions, but to our knowledge, few authors have investigated the effect of heat on referees' performance.

The FIFA rules give referees a crucial role and responsibility. A soccer match is played by 2 teams, each consisting of 7 to 11 players, but is controlled by a referee: hence, the central referee "has full authority to enforce the laws of the game in connection with the match to which he has been appointed," and "the decisions of the referee regarding facts connected with play, including whether or not a goal is scored and the result of the match, are final."<sup>13</sup> Some researchers<sup>14–18</sup> examined the underlying mechanisms that led to incorrect decisions. It has been established that a central referee's decisions are strongly influenced by crowd noise,<sup>16,18</sup> whereas flash lag and optical error could explain all flag and a large portion of nonflag errors made by assistant referees.<sup>14,15</sup> However, the nearer to the action the referee is, the less the decision-making error. Mallo et al<sup>17</sup> reported that the error percentage was low when a dozen meters separated the central referee from the incident. Therefore, the central and assistant referees run several kilometers per game to be as close as possible to the action.<sup>19,20</sup> An increase in the percentage of erroneous decision making at the end of a game, with a 23% peak value recorded in the last 15-minute match period, has also been observed.<sup>17</sup> This result may be explained by crowd noise and fatigue. In fact, Krstrup et al<sup>21</sup> observed a

decrease in running displacements for central and assistant referees in this period of the game. The central referees covered 10 000 m at nearly 80% of their maximal oxygen uptake ( $\dot{V}O_{2\max}$ ), and the assistant referees covered 7500 m at 65% of  $\dot{V}O_{2\max}$  (ie, 77% of maximal heart rate value) on average during a game.<sup>19,20</sup> Analysis of the distance-time regression coefficients revealed no difference between the referees' and players' within-match rates of change for total distance covered, high-speed running, or sprinting.<sup>22</sup> Additionally, both the central and assistant referees executed unorthodox movement patterns that increased energy expenditure over normal locomotion during the match.<sup>20</sup>

Referees' physical activity during a match induced a mean total body water loss of  $1.60 \pm 0.13$  L (ie, mild 2.0% dehydration).<sup>23</sup> Studies investigating the effects of water restriction, heat, or physical exertion (or a combination of these) on physical, visuomotor, psychomotor, and cognitive performance indicated that 2.0% dehydration induced a reduction in physical,<sup>21</sup> psychomotor,<sup>24</sup> and cognitive performances.<sup>25</sup> Irwin et al<sup>26</sup> showed that 2.5% dehydration impaired cognitive function in a temperate environment ( $22.0^\circ\text{C} \pm 2.0^\circ\text{C}$ , 60.0%–70.0% relative humidity). Body water loss was related to an increase in cortisol level,<sup>27</sup> which could induce decreases in vigilance, attention span, memory, and reasoning.<sup>27,28</sup> Mild dehydration significantly impaired performance in tasks that required attention<sup>29</sup> and distance judgment,<sup>30</sup> which could affect the central and assistant referees' decisions.<sup>15</sup> Edwards et al<sup>31</sup> also found a decrease in soccer performance when fluid intake was denied. Moderate water loss was accompanied by a core temperature of  $39.28^\circ\text{C} \pm 0.35^\circ\text{C}$ , which was higher than the core temperature measured in fluid-replacement conditions.<sup>31</sup> Nielsen et al<sup>32,33</sup> reported that acute exposure to exercise in humid or dry heat caused an increase in core temperature to  $39.70^\circ\text{C} \pm 0.15^\circ\text{C}$ , which limited exercise performance and therefore could exacerbate the decision-making error if the referee was not in the right location to properly observe play. Additionally, a percentage of psychomotor error was also related to the heat. Epstein et al<sup>24</sup> reported that psychomotor performance was reduced well before a decrease in physiologic factors in the heat. They also showed that 2-hour exposure at  $35.0^\circ\text{C}$  induced 2.5% dehydration at rest.<sup>24</sup>

Hyperthermia coupled with mild dehydration due to exercise in the heat appeared to impair physical and cognitive performance and, therefore, possibly referees' decision making. However, it appeared that thermal strain induced by hot conditions had a minimal effect upon cognitive function when dehydration was prevented.<sup>34–36</sup> Parker et al<sup>36</sup> reported that neither core temperature nor cognitive functions were affected by mild heat stress when coupled with modest rehydration compared with a temperate environment. Caldwell et al<sup>34</sup> also found that liquid cooling reduced maximal core temperature and prevented cognitive impairment. Thus, rehydration could partially reverse the adverse effects induced by exercise performed in the heat. Silva et al<sup>37</sup> observed that hydration by fluid ingestion equivalent to 1.0% of the referees' baseline body mass (half before the match and half during half time) reduced body weight loss and played a positive role in physical performance. Recently, Edmonds et al<sup>38</sup> reported that subjective thirst affected the speed of responding. They

concluded that the preventive effect of water supplementation on response speed was the result of the subjective thirst sensation. In fact, Edmonds et al<sup>38</sup> showed a greater mean response time after water ingestion compared with no water ingestion. Participants were also less confused if they had a drink. Moreover, ratings of "tiredness" and being "tense" were higher if individuals were thirsty compared with those who were less thirsty.<sup>38</sup> Hence, the potential for dehydration to impair cognition appears small and related primarily to distraction or discomfort,<sup>13,39</sup> but in addition to the exercise and decision-making impairment induced by mild dehydration and crowd noise, this could explain some errors. In this context, a significant proportion of all referees' decisions during the Brazilian competition were commented on and challenged, as potentially will be the case in the next FIFA World Cups, particularly with the extreme temperatures in Qatar.<sup>40</sup> The effects of heat on core temperature and dehydration plus the increased sprint velocity of soccer players in the heat<sup>41</sup> make the referees' tasks more challenging. We strongly argue that the hydration status of referees should be taken into account to prevent high body core temperature and high levels of thirst and, therefore, reduce referees' errors and misjudgments.

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